

RESEARCH ARTICLE

Open Access



The *Global Alliance for Infections in Surgery*: defining a model for antimicrobial stewardship—results from an international cross-sectional survey

Massimo Sartelli^{1*}, Francesco M. Labricciosa², Pamela Barbadoro², Leonardo Pagani³, Luca Ansaloni⁴, Adrian J. Brink^{5,6}, Jean Carlet⁷, Ashish Khanna⁸, Alain Chichom-Mefire⁹, Federico Coccolini¹⁰, Salomone Di Saverio¹¹, Addison K. May¹², Pierluigi Viale¹³, Richard R. Watkins^{14,15}, Luigia Scudeller¹⁶, Lilian M. Abbo¹⁷, Fikri M. Abu-Zidan¹⁸, Abdulrashid K. Adesunkanmi¹⁹, Sara Al-Dahir²⁰, Majdi N. Al-Hasan²¹, Halil Alis²², Carlos Alves²³, André R. Araujo da Silva²⁴, Goran Augustin²⁵, Miklosh Bala²⁶, Philip S. Barie²⁷, Marcelo A. Beltrán²⁸, Aneel Bhangu²⁹, Belefquih Bouchra³⁰, Stephen M. Brecher^{31,32}, Miguel A. Caínzos³³, Adrian Camacho-Ortiz³⁴, Marco Catani³⁵, Sujith J. Chandy³⁶, Asri Che Jusoh³⁷, Jill R. Cherry-Bukowiec³⁸, Osvaldo Chiara³⁹, Elif Colak⁴⁰, Oliver A. Cornely⁴¹, Yunfeng Cui⁴², Zaza Demetrasvili⁴³, Belinda De Simone⁴⁴, Jan J. De Waele⁴⁵, Sameer Dhingra^{46,47}, Francesco Di Marzo⁴⁸, Agron Dogjani⁴⁹, Gereltuya Dorj⁵⁰, Laurent Dortet⁵¹, Therese M. Duane⁵², Mutasim M. Elmangory⁵³, Mushira A. Enani⁵⁴, Paula Ferrada⁵⁵, J. Esteban Foianini⁵⁶, Mahir Gachabayov⁵⁷, Chinmay Gandhi⁵⁸, Wagih Mommtaz Ghnnam⁵⁹, Helen Giamarellou⁶⁰, Georgios Gkiokas⁶¹, Harumi Gomi⁶², Tatjana Goranovic⁶³, Ewen A. Griffiths⁶⁴, Rosio I. Guerra Gronerth⁶⁵, Julio C. Haidamus Monteiro⁶⁶, Timothy C. Hardcastle⁶⁷, Andreas Hecker⁶⁸, Adrien M. Hodonou⁶⁹, Orestis Ioannidis⁷⁰, Arda Isik⁷¹, Katia A. Iskandar⁷², Hossein S. Kafil⁷³, Souha S. Kanj⁷⁴, Lewis J. Kaplan⁷⁵, Garima Kapoor⁷⁶, Aleksandar R. Karamarkovic⁷⁷, Jakub Kenig⁷⁸, Ivan Kerschaever⁷⁹, Faryal Khamis⁸⁰, Vladimir Khokha⁸¹, Ronald Kiguba⁸², Hong B. Kim⁸³, Wen-Chien Ko⁸⁴, Kaoru Koike⁸⁵, Iryna Kozlovskaya⁸⁶, Anand Kumar⁸⁷, Leonel Lagunes⁸⁸, Rifat Latifi⁸⁹, Jae G. Lee⁹⁰, Young R. Lee⁹¹, Ari Leppäniemi⁹², Yousheng Li⁹³, Stephen Y. Liang⁹⁴, Warren Lowman⁹⁵, Gustavo M. Machain⁹⁶, Marc Maegele⁹⁷, Piotr Major⁹⁸, Sydney Malama⁹⁹, Ramiro Manzano-Nunez¹⁰⁰, Athanasios Marinis¹⁰¹, Isidro Martinez Casas¹⁰², Sanjay Marwah¹⁰³, Emilio Maseda¹⁰⁴, Michael E. McFarlane¹⁰⁵, Ziad Memish¹⁰⁶, Dominik Mertz¹⁰⁷, Cristian Mesina¹⁰⁸, Shyam K. Mishra¹⁰⁹, Ernest E. Moore¹¹⁰, Akutu Munyika¹¹¹, Eleftherios Mylonakis¹¹², Lena Napolitano¹¹³, Ionut Negoii¹¹⁴, Milica D. Nestorovic¹¹⁵, David P. Nicolau¹¹⁶, Abdelkarim H. Omari¹¹⁷, Carlos A. Ordonez¹¹⁸, José-Artur Paiva¹¹⁹, Narayan D. Pant¹²⁰, Jose G. Parreira¹²¹, Michal Pędziwiatr¹²², Bruno M. Pereira¹²³, Alfredo Ponce-de-Leon¹²⁴, Garyphallia Poulakou¹²⁵, Jacobus Preller¹²⁶, Céline Pulcini¹²⁷, Guntars Pupelis¹²⁸, Martha Quiodettis¹²⁹, Timothy M. Rawson¹³⁰, Tarcisio Reis¹³¹, Miran Rems¹³², Sandro Rizoli¹³³, Jason Roberts¹³⁴, Nuno Rocha Pereira¹³⁵, Jesús Rodríguez-Baño¹³⁶, Boris Sakakushev¹³⁶, James Sanders¹³⁷, Natalia Santos¹³⁸, Norio Sato¹³⁹, Robert G. Sawyer¹⁴⁰, Sandro Scarpelini¹⁴¹, Loredana Scoccia¹⁴², Nusrat Shafiq¹⁴³, Vishalkumar Shelat¹⁴⁴, Costi D. Sifri¹⁴⁵, Boonying Siribumrungwong¹⁴⁶, Kjetil Søreide^{147,148}, Rodolfo Soto¹⁴⁹, Hamilton P. de Souza¹⁵⁰, Peep Talving¹⁵¹, Ngo Tat Trung¹⁵², Jeffrey M. Tessier¹⁵³, Mario Tumbarello¹⁵⁴, Jan Ulrych¹⁵⁵, Selman Uranues¹⁵⁶, Harry Van Goor¹⁵⁷, Andras Vereczkei¹⁵⁸, Florian Wagenlehner¹⁵⁹, Yonghong Xiao¹⁶⁰, Kuo-Ching Yuan¹⁶¹, Agnes Wechsler-Fördös¹⁶², Jean-Ralph Zahar¹⁶³, Tanya L. Zakrisson¹⁶⁴, Brian Zuckerbraun¹⁶⁵, Wietse P. Zuidema¹⁶⁶ and Fausto Catena¹⁶⁷

* Correspondence: m.sartelli@virgilio.it¹Department of Surgery, Macerata Hospital, Macerata, Italy

Full list of author information is available at the end of the article



© The Author(s). 2017 **Open Access** This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (<http://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (<http://creativecommons.org/publicdomain/zero/1.0/>) applies to the data made available in this article, unless otherwise stated.

Abstract

Background: Antimicrobial Stewardship Programs (ASPs) have been promoted to optimize antimicrobial usage and patient outcomes, and to reduce the emergence of antimicrobial-resistant organisms. However, the best strategies for an ASP are not definitively established and are likely to vary based on local culture, policy, and routine clinical practice, and probably limited resources in middle-income countries. The aim of this study is to evaluate structures and resources of antimicrobial stewardship teams (ASTs) in surgical departments from different regions of the world.

Methods: A cross-sectional web-based survey was conducted in 2016 on 173 physicians who participated in the AGORA (Antimicrobials: A Global Alliance for Optimizing their Rational Use in Intra-Abdominal Infections) project and on 658 international experts in the fields of ASPs, infection control, and infections in surgery.

Results: The response rate was 19.4%. One hundred fifty-six (98.7%) participants stated their hospital had a multidisciplinary AST. The median number of physicians working inside the team was five [interquartile range 4–6]. An infectious disease specialist, a microbiologist and an infection control specialist were, respectively, present in 80.1, 76.3, and 67.9% of the ASTs. A surgeon was a component in 59.0% of cases and was significantly more likely to be present in university hospitals (89.5%, $p < 0.05$) compared to community teaching (83.3%) and community hospitals (66.7%). Protocols for pre-operative prophylaxis and for antimicrobial treatment of surgical infections were respectively implemented in 96.2 and 82.3% of the hospitals. The majority of the surgical departments implemented both persuasive and restrictive interventions (72.8%). The most common types of interventions in surgical departments were dissemination of educational materials (62.5%), expert approval (61.0%), audit and feedback (55.1%), educational outreach (53.7%), and compulsory order forms (51.5%).

Conclusion: The survey showed a heterogeneous organization of ASPs worldwide, demonstrating the necessity of a multidisciplinary and collaborative approach in the battle against antimicrobial resistance in surgical infections, and the importance of educational efforts towards this goal.

Keywords: Antibiotics, Infections, Surgery, Antimicrobial stewardship

Background

Antimicrobial Stewardship Programs (ASPs) have been promoted to optimize antimicrobial usage and patient outcomes and reduce the emergence of antimicrobial-resistant organisms. However, the best strategies for an ASP are not definitively established and are likely to vary based on local culture, policy and routine clinical practice, and probably limited resources in middle-income countries [1, 2]. Many hospitals remain without formal programs and those that do continue to struggle with gaining acceptance across service lines [3]. Moreover, identifying optimal efforts to impact system change has been challenging [4].

Restriction strategies may be effective at controlling use but raise issues of prescriber autonomy and require a large personnel commitment. Encouraging multidisciplinary collaboration within health systems to ensure that prophylactic, empirical, and targeted use of antimicrobial agents results in optimal patient outcomes is mandatory in the current era of antimicrobial resistance.

A panel of experts from the Surgical Infection Society (SIS) and World Society of Emergency Surgery (WSES) has recently published a review with the aim of defining the role of surgeons within the ASPs. The panel proposed that the best means of improving antimicrobial stewardship in surgical units worldwide should involve collaboration among various specialties within institutions including prescribing clinicians and pharmacists [5].

In 2016, a multidisciplinary task force from 79 different countries joined a global project to develop a consensus on the rational use of antimicrobials for patients with intra-abdominal infections (IAIs). The project has been termed AGORA (Antimicrobials: A Global Alliance for Optimizing their Rational Use in Intra-Abdominal Infections) [1].

Recently the *Global Alliance for Infections in Surgery* was founded and experts from 87 countries worldwide joined the highly diverse and skilled International Advisory Board. This alliance, promoted by the WSES, includes an interdisciplinary group of hospital administrators, epidemiologists, infection control specialists, infectious disease specialists, microbiologists, clinical pharmacologists and hospital pharmacists, surgeons, and intensivists. The mission of this alliance is to educate healthcare providers promoting the standards of care in managing infections in surgery worldwide [6]. Therefore, this study was conducted to evaluate the structure and resources of antimicrobial stewardship teams (ASTs) in surgical departments from different regions of the world.

Methods

We conducted a cross-sectional electronic survey evaluating the structure and resources of ASTs in surgical departments. The survey was designed by a multidisciplinary team of investigators including an epidemiologist,

a surgeon, an infectious diseases physician, a pharmacologist, and a microbiologist. The questionnaire was piloted among five physicians for face and content validity.

The 24-item self-administered questionnaire collected information from multidisciplinary experts—mostly physicians—about characteristics and composition of the hospital team, implementation of local procedures, availability of antimicrobial use monitoring and surveillance systems, presence of an ASP, and related interventions (Additional file 1). An electronic invitation with a link to the survey was sent to 831 physicians: 173 physicians who participated in the AGORA project [1], and a large number (658) of international experts in the fields of antimicrobial stewardship, infection control, and infections in surgery identified after a thorough investigation using the PubMed database. The survey was Internet-based (using <http://www.docs.google.com>). Participation was voluntary but not anonymous; however, the confidentiality of respondents and their choices was ensured. No incentives were provided to the respondents. The study was open for 6 weeks between September 30 and November 11, 2016. Reminders were sent to all those who had not replied after 1 and 3 weeks. Due to the characteristics of the survey, a response rate ranging between 15 and 25% was expected.

Data were entered in an Excel database (Microsoft Corporation, Redmond, Washington, USA) and analyzed using Stata 11.0 software package (StataCorp, College Station, TX). Descriptive analyses included medians and interquartile ranges (IQR) for continuous variables or frequency (%) for categorical variables. The two-sided chi-square or Fisher's exact test was used for categorical variables, as appropriate. All tests were two-sided, and p values of 0.05 or lower were considered statistically significant.

Results

Baseline data: coverage, response rate, working setting, and professional profile

A total of 161 (19.4%) of the 831 experts who were contacted by email completed the survey after two reminders. One incomplete survey was excluded from the study. In two cases the participants were from the same institution and only one survey was considered. One hundred fifty-eight responses were included in our analysis. Participants work settings and professional profiles are summarized in Table 1.

The response rate was similar to that of previous studies promoted by WSES [1, 7, 8].

As in the other WSES studies [1, 7, 8], participants were not homogeneously distributed across all geographic regions of the world due to the difficulty in recruiting

participants in some areas of the world. However all geographic regions were represented in the survey.

Characteristics of the team

One hundred fifty-six (98.7%) participants stated their hospital had a multidisciplinary AST. Ninety participants (90/156, 57.7%) declared they were currently members of the team, with no difference in frequency between different WHO regions. The median number of physicians working inside the team was five [IQR 4–6]. Characteristics of the team are in Table 2.

One hundred thirty-five (135/158, 85.4%) participants had at least one surgeon with an interest or skills in surgical infections within the surgical department of their hospital; a surgeon was significantly more likely to be present in university hospitals (89.5%, two-sided chi-square test $p < 0.05$) compared to community teaching hospitals (83.3%) and community hospitals (66.7%).

Implementation of protocols and monitoring systems

Implementation of protocols and monitoring systems in 158 hospitals are reported in Table 3.

The vast majority of respondents (152/158, 96.2%) stated that their hospitals have a protocol for pre-operative prophylaxis. The protocol covered all surgical wards in 124 (78.5%) cases. A protocol for antimicrobial treatment of surgical infections was available in 130 (82.3%) hospitals; however, only 70 (44.3%) had it available in every surgical ward. One hundred twenty-eight (81.0%) hospitals had both a protocol for peri-operative prophylaxis and for antimicrobial treatment of surgical infections available, while four (4/158, 2.5%) hospitals lacked both.

Among 130 surgical wards implementing a protocol for antimicrobial treatment of surgical infections, 97 (74.6%) participants stated it included interventions to reduce the duration of therapy, 88 (67.7%) interventions to switch selected antimicrobials from intravenous-to-oral therapy, 78 (60.0%) interventions for alternative dosing strategies based on pharmacokinetics and pharmacodynamics, with significant difference between community hospitals (11.1%, two-sided Fischer's exact test $p < 0.05$) compared to university (57.0%) and community teaching (60.0%) hospitals. Thirty-five (26.9%) participants reported the use of biological markers - such as procalcitonin to decrease antimicrobial use in critically ill patients.

Implementations of ASPs and related interventions

One hundred fifty-five (155/158, 98.1%) participants declared their hospital had an ASP running.

Our survey showed that 30 (19.4%) hospitals have developed persuasive interventions, 17 (11.0%) restrictive interventions and 108 (69.7%) both of them.

Table 1 Participants' working settings and professional profiles

Characteristics	African region <i>n</i> = 8	Eastern- Mediterranean region <i>n</i> = 13	European region <i>n</i> = 67	Region of Americas <i>n</i> = 47	South-East Asia region <i>n</i> = 8	Western Pacific region <i>n</i> = 15	Total <i>n</i> = 158
Type of hospital, <i>n</i> (%)							
- University hospital	5 (62.5)	6 (46.1)	50 (74.6)	35 (74.5)	6 (75.0)	12 (80.0)	114 (72.1)
- Community teaching hospital	2 (25.0)	3 (23.1)	14 (20.9)	9 (19.1)	1 (12.5)	1 (6.7)	30 (19.0)
- Community hospital	0	2 (15.4)	3 (4.5)	1 (2.1)	1 (12.5)	2 (13.3)	9 (5.7)
- Other	1 (12.5)	2 (15.4)	0	2 (4.3)	0	0	5 (3.2)
Hospital setting, <i>n</i> (%)							
- Urban	5 (62.5)	10 (76.9)	65 (97.0)	44 (93.6)	6 (75.0)	14 (93.3)	144 (91.1)
- Suburban	3 (37.5)	3 (23.1)	2 (3.0)	1 (2.1)	2 (25.0)	0	11 (7.0)
- Rural	0	0	0	2 (4.3)	0	1 (6.7)	3 (1.9)
Hospital inpatient beds, <i>n</i> (%)							
- ≤100	0	2 (15.4)	3 (4.5)	1 (2.1)	0	0	6 (3.8)
- 101–500	3 (37.5)	5 (38.5)	15 (22.4)	10 (21.3)	2 (25.0)	3 (20.0)	38 (24.1)
- 501–1000	3 (37.5)	5 (38.5)	27 (40.3)	28 (59.6)	3 (37.5)	1 (6.7)	67 (42.4)
- ≥ 1000	2 (25.0)	1 (7.7)	22 (32.8)	8 (17.0)	3 (37.5)	11 (73.3)	47 (29.7)
Profession, <i>n</i> (%)							
Epidemiologist	1 (12.5)	0	2 (3.0)	1 (2.1)	0	0	4 (2.5)
Hospital administrator	0	0	0	0	0	0	0
Clinical pharmacologist	0	1 (7.7)	0	4 (8.5)	1 (12.5)	1 (6.7)	7 (4.4)
Hospital pharmacist	0	0	1 (1.5)	1 (2.1)	1 (12.5)	1 (6.7)	4 (2.5)
Infection control specialist	0	0	1 (1.5)	1 (2.1)	0	0	2 (1.3)
Infectious diseases specialist	0	4 (30.8)	10 (14.9)	10 (21.3)	0	5 (33.3)	29 (18.4)
Intensivist	1 (12.5)	0	5 (7.5)	2 (4.3)	0	1 (6.7)	9 (5.7)
Microbiologist	3 (37.5)	3 (23.1)	1 (1.5)	1 (2.1)	3 (37.5)	0	11 (7.0)
Surgeon	3 (37.5)	5 (38.5)	44 (65.7)	24 (51.1)	3 (37.5)	6 (40.0)	85 (53.8)
Other	0	0	3 (4.5)	3 (6.4)	0	1 (6.7)	7 (4.4)

Twenty-three surgical departments (23/136, 16.9%) have developed persuasive interventions, 14 (10.3%) restrictive interventions and 99 (72.8%) both of them.

The most common types of interventions in surgical departments were dissemination of educational materials (62.5%), expert approval (61.0%), audit and feedback (55.1%), educational outreach (53.7%), and compulsory order forms (51.5%).

Types of ASPs and related interventions in surgical departments and in all hospital wards are described in detail in Table 4.

Six (6/41, 14.6%) surgical departments implementing a formulary restriction do not perform any monitoring system of used antimicrobials, and 4 (4/41, 9.8%) do not carry out any systematic reports about resistance data. Furthermore, 6 (7/70, 10.0%) surgical departments using a compulsory order form do not perform any monitoring system of used antimicrobials, and 11 (11/70, 15.7%) do not carry out any systematic reports about resistance data.

One hundred twenty-five (125/158, 79.1%) participants stated their hospital had carried out structural interventions to improve ASPs in the last 5 years. Sixty-nine (43.7%) changed from paper to computerized records, 74 (46.8%) implemented rapid laboratory testing, 32 (20.3%) introduced computerized decision support systems, 69 (43.7%) introduced organization of quality monitoring mechanisms and 29 (18.4%) implemented other structural interventions.

Characteristics of the implementation of protocols, monitoring systems, and ASPs interventions in surgical departments are detailed in Table 5.

Discussion

Antimicrobial stewardship programs (ASP) are a key strategy to curb the spread of antibiotic resistance [3, 9]. The best strategies for an ASP are not definitively established and are likely to vary based on local routine clinical practice [7], despite several guidelines on the topic [9, 10].

Table 2 Characteristics of the team in 156 hospitals

Characteristics	n (%)
Components	
- Epidemiologist	64 (41.0)
- Hospital administrator	73 (46.8)
- Clinical pharmacologist	8 (5.1)
- Hospital pharmacist	95 (60.9)
- Infection control specialist	106 (67.9)
- Infectious disease specialist	125 (80.1)
- Intensivist	76 (48.7)
- Microbiologist	119 (76.3)
- Surgeon	92 (59.0)
- Other	11 (7.1)
- Infectious disease specialist AND hospital pharmacist/pharmacologist	87 (55.8)
Frequency of meetings	
- More than once a week	15 (9.6)
- Once a week	26 (16.7)
- Twice a month	13 (8.3)
- Once a month	58 (37.2)
- Less than once a month	27 (17.3)
- Only as necessary	17 (10.9)

Successful ASPs should focus on collaboration between healthcare professionals in order to share knowledge and best practices. It is essential for an ASP to have at least one member who is an infectious diseases specialist. Pharmacists with advanced training or longstanding clinical experience in infectious diseases are also key actors for the design and implementation of the stewardship program interventions [11]. Infection control specialists and hospital epidemiologists should coordinate efforts on monitoring and preventing healthcare-associated infections and in analyzing and reporting “real-time” data to prevent infections, improve antimicrobial use, and minimize secondary spread of resistance. Microbiologists should actively guide the proper use of tests and the flow of laboratory results. Being involved in providing surveillance data on antimicrobial resistance, they should provide periodic reports on antimicrobial resistance data allowing

the multidisciplinary team to determine the ongoing burden of antimicrobial resistance in the hospital. Moreover, timely and accurate reporting of microbiology susceptibility test results allows selection of more appropriate targeted therapy, and may help reduce broad-spectrum antimicrobial use.

Surgeons with adequate knowledge in surgical infections and surgical anatomy when involved in ASPs may audit antibiotic prescriptions, provide feedback to the prescribers and integrate best practices of antimicrobial use among surgeons, and act as champions among colleagues. Although many surgeons are aware of the problem of antimicrobial resistance, most underestimate it in their own hospital [1]. Very few studies have been published on the role of ASPs in general surgical departments. In 2015, Cakmakci [12] suggested that the engagement of surgeons in ASPs might be crucial to their success. In 2013, however, Duane et al. showed poor compliance of surgical services with ASP recommendations [13]. Surgeons need to take part in addressing the global issue of antimicrobial resistance. Failure to do so will be catastrophic to patients and programs [3].

Infections are the main factors contributing to mortality in intensive care units (ICU) [14].

Intensivists have a critical role in treating multidrug resistant organisms in ICUs in critically ill patients. They have a crucial role in prescribing antimicrobial agents for our most challenging patients and are at the forefront of a successful ASP [15].

Finally, without adequate support from hospital administration, the ASP will be inadequate or inconsistent since the programs do not generate revenue [16]. Engagement of hospital administration has been confirmed as a key factor for both developing and sustaining an ASP [17].

In most cases, our survey demonstrated that ASPs do not involve a true multi-disciplinary approach.

An infectious diseases specialist and a hospital pharmacist were part of the team in 125 (80.1%) and in 95 (60.9%) cases, respectively. Only 87 (55.8%) teams included both an infectious diseases specialist and a hospital pharmacist. An infection control specialist and a hospital epidemiologist were part of the team in 106 (67.9%) and in 64 (41.0%) cases, respectively. It is possible that in some hospitals,

Table 3 Implementation of protocols and monitoring systems in 158 hospitals

Implementation of protocols and monitoring systems	All hospital wards n (%)	Some hospital wards, including surgical wards n (%)		Some hospital wards, not including surgical wards n (%)	No hospital wards n (%)
		Every surgical wards	Some surgical wards		
- SAP protocol	NA	124 (78.5)	28 (17.7)	NA	6 (3.8)
- TIS protocol	NA	70 (44.3)	60 (38.0)	NA	28 (17.7)
- UAMS	84 (53.2)	45 (28.5)		9 (5.7)	20 (12.7)
- RDSR	104 (65.8)	26 (16.5)		7 (4.4)	21 (13.3)

SAP Surgical antimicrobial prophylaxis, TIS therapy for infections in surgery, UAMS used antimicrobial monitoring system, RDSR resistance data systematic report

Table 4 Difference in type of ASPs and related implemented types of interventions in surgical departments and non-surgical departments

Characteristics	Surgical departments, <i>n</i> = 136 <i>n</i> (%)	Other departments, <i>n</i> = 19 <i>n</i> (%)	<i>P</i> value	Total, <i>n</i> = 155 <i>n</i> (%)
Type of ASPs				
- Persuasive interventions	23 (16.9)	7 (36.8)	0.06 ^a	30 (19.4)
- Restrictive interventions	14 (10.3)	3 (15.8)	0.44 ^a	17 (11.0)
- Both	99 (72.8)	9 (47.4)	<0.05	108 (69.7)
Type of interventions				
- Dissemination of educational materials	85 (62.5)	8 (42.1)	0.15	93 (60.0)
- Reminders	56 (41.2)	8 (42.1)	1.00	64 (41.3)
- Audit and feedback	75 (55.1)	4 (21.1)	<0.05	79 (51.0)
- Educational outreach	73 (53.7)	10 (52.6)	1.00	83 (53.6)
- Other persuasive interventions	23 (16.9)	3 (15.8)	1.00 ^a	26 (16.8)
- Compulsory order form	70 (51.5)	7 (36.8)	0.34	77 (49.7)
- Expert approval	83 (61.0)	5 (26.3)	<0.05	88 (56.8)
- Restriction by removal	41 (30.1)	2 (10.5)	0.13	43 (27.7)
- Review and make changes	36 (26.5)	1 (5.3)	<0.05 ^a	37 (23.9)
- Other restrictive interventions	10 (7.4)	3 (15.8)	0.20 ^a	13 (8.4)

All *p* values were calculated using two-sided chi-square test unless otherwise noted

ASP antimicrobial stewardship program

^aCalculated using two-sided Fisher's exact test

AMS and infection prevention and control team are two separate entities, which collaborate. A microbiologist was part of the team in 119 (76.3%) cases. A surgeon was part of the team in 92 (59.0%) cases and an intensivist in 76 (48.6%) cases. A hospital administrator was part of the team only in 73 (46.8%) cases. Interestingly a surgeon was significantly more likely to be part of the team in university hospitals (89.5%, two-sided chi-square test $p < 0.05$) compared to community teaching (83.3%) and community non-teaching hospital (66.7%).

Strategies of ASPs should be tailored based on individual hospital characteristics and personnel and resources available. The Infectious Diseases Society of America/ Society for Healthcare Epidemiology of America (IDSA/ SHEA) guidelines identified two core proactive evidence-based strategies and several supplemental strategies for promoting antimicrobial stewardship [7, 8]: first, a restrictive strategy based on a proactive strategy of either formulary restriction or a requirement for pre-approval for specific drugs or both, and second, a persuasive strategy of performing prospective audit with intervention and feedback to the prescriber.

Our survey showed that 23 (16.9%) surgical departments have developed persuasive interventions, 14 (10.3%) restrictive interventions and 99 (72.8%) both of them. ASP policies should be based on both international/national antibiotic guidelines, and tailored to local microbiology and resistance patterns. Local clinical practice guidelines and algorithms can be an effective way to standardize

prescribing practices based on the country's epidemiology. Standardizing a shared protocol of antimicrobial prophylaxis should represent the first step of any Antimicrobial Stewardship program.

One hundred fifty-two (96.2%) participants stated their hospitals have a protocol for surgical antibiotic prophylaxis. Among the 158 hospitals, a protocol for antibiotic prophylaxis is present in all surgical wards in 124 (78.5%) of hospitals while only in some surgical wards in 28 (17.7%) hospitals.

A protocol for antibiotic treatment was present in all surgical wards in 70 (44.3%) hospitals, while only in some surgical wards in 60 (38.0%) hospitals. Among 130 hospitals implementing a protocol for antimicrobial treatment of surgical infections, 97 (74.6%) participants stated that it included interventions to reduce the duration of therapy, 88 (67.7%) interventions to switch select antimicrobials from intravenous-to-oral therapy, 78 (60.0%) interventions for alternative dosing strategies based on pharmacokinetic and pharmacodynamic principles, with substantial difference between community hospitals (11.1%, two-sided Fischer's exact test $p < 0.05$), university (57.0%) and community teaching (60.0%) ones. Thirty-five (26.9%) participants admitted to the use of biological markers - such as procalcitonin - to decrease antimicrobial use in critically ill patients.

In any healthcare setting, a significant amount of time and energy should be spent on infection control. Surveillance studies can help clinicians to identify trends in

Table 5 Implementation of protocols, monitoring systems and ASPs interventions in surgical departments related to working setting and team components

Variables	PAP protocol implemented n, (%), p	TIS protocol implemented n, (%), p	Monitoring system of used antimicrobials n, (%), p	Resistance data systematic reports n, (%), p	ASP implemented n, (%), p	Structural intervention n, (%), p
Number of bed						
Less than 100, n = 6	5 (83.3) 1.00 ^a	4 (66.7) 0.29 ^a	4 (66.7) 0.30 ^a	4 (66.7) 0.29 ^a	3 (50.0) 0.58 ^a	3 (50.0) 0.10 ^a
101–500, n = 38	37 (97.4) 1.00 ^a	32 (84.2) 0.57	29 (76.3) 0.80	30 (78.9) 1.00	32 (84.2) 0.75	22 (57.9) <0.05 ^a
501–1000, n = 67	62 (92.5) 0.08 ^a	53 (79.1) 0.49	53 (79.1) 0.62	56 (83.6) 0.87	56 (83.6) 0.75	58 (86.6) <0.05 ^a
More than 1000, n = 47	47 (100.0) 0.18 ^a	40 (85.1) 0.71	42 (89.4) 0.16	39 (83.0) 1.00	39 (83.0) 1.00	41 (87.2) 0.16
Hospital setting						
Urban, n = 144	140 (97.2) 0.09	118 (81.9) 1.00 ^a	119 (82.6) 0.29 ^a	122 (84.7) <0.05 ^a	120 (83.3) 0.40 ^a	97 (67.4) 0.17 ^a
Suburban and rural, n = 14	12 (85.7) 0.09	12 (85.7) 1.00 ^a	11 (78.6) 0.29 ^a	9 (64.3) <0.05 ^a	10 (71.4) 0.40 ^a	9 (64.3) 0.17 ^a
Type of hospital						
University hospital, n = 114	110 (96.5) 0.67 ^a	92 (80.7) 0.55	94 (82.5) 0.84	98 (86.0) 0.08	92 (80.7) 0.84	95 (83.3) <0.05
Community teaching hospital, n = 30	29 (96.7) 1.00 ^a	27 (90.0) 0.33	27 (90.0) 0.60	24 (80.0) 0.92	26 (86.7) 0.77 ^a	22 (73.3) 0.54
Community hospital, n = 9	8 (88.9) 0.30 ^a	8 (88.9) 1.00 ^a	7 (77.8) 0.67 ^a	5 (55.6) 0.05 ^a	9 (100.0) 1.00 ^a	3 (33.3) <0.05 ^a
Other, n = 5	5 (100.0) 1.00 ^a	3 (60.0) 0.21 ^a	3 (60.0) <0.05 ^a	4 (80.0) 0.21 ^a	4 (80.0) 0.52 ^a	4 (80.0) 1.00 ^a
Components of the team						
Epidemiologist, n = 64	62 (96.9) 1.00 ^a	53 (82.8) 1.00	52 (81.3) 1.00	59 (92.2) <0.05	52 (81.3) 1.00	53 (82.8) 0.46
Infection control specialist, n = 106	103 (97.2) 0.40 ^a	90 (84.9) 0.31	91 (85.8) 0.08	89 (84.0) 0.57	89 (84.0) 1.00	82 (77.4) 0.79
Hospital administrator, n = 73	71 (97.3) 0.69 ^a	65 (89.0) 0.06	61 (83.6) 0.71	61 (83.6) 0.86	63 (86.3) 0.29	59 (80.8) 0.49
Hospital pharmacologist, n = 95	94 (98.9) <0.05 ^a	80 (84.2) 0.57	80 (84.2) 0.42	82 (86.3) 0.16	83 (87.4) 0.29	79 (83.2) 0.08
Hospital pharmacist, n = 8	7 (87.5) 0.27 ^a	6 (75.0) 0.43 ^a	7 (87.5) 0.55 ^a	5 (62.5) 0.15 ^a	7 (87.5) 0.36 ^a	3 (37.5) <0.05 ^a
Infectious diseases specialist, n = 125	120 (96.0) 1.00 ^a	100 (80.0) 0.23	104 (83.2) 0.47	103 (82.4) 1.00	107 (85.6) 0.15 ^a	95 (76.0) 0.50
Intensivist, n = 76	74 (97.4) 0.68 ^a	65 (85.5) 0.41	66 (86.8) 0.16	63 (82.9) 1.00	66 (86.8) 0.80	60 (78.9) 1.00
Microbiologist, n = 119	119 (100.0) 0.64 ^a	98 (82.4) 1.00	96 (80.7) 0.75	100 (84.0) 0.44	98 (82.4) 0.82	91 (76.5) 0.46
Surgeon, n = 92	88 (95.7) 1.00 ^a	80 (87.0) 0.11	77 (83.7) 0.56	77 (83.7) 0.73	76 (82.6) 0.70	70 (76.1) 0.61
Other, n = 11	11 (100.0) 1.00 ^a	9 (81.8) 1.00 ^a	11 (100.0) 0.22 ^a	10 (90.9) 0.69 ^a	10 (90.9) 1.00 ^a	8 (72.7) 0.70 ^a

All p values were calculated using two-sided chi-square test unless otherwise noted

PAP pre-operative antimicrobial prophylaxis, TIS therapy for infections in surgery, ASP antimicrobial stewardship program

^aCalculated using two-sided Fisher's exact test. ASP antimicrobial stewardship program

pathogens incidence and antimicrobial resistance, including identification of emerging pathogens at local level. The survey showed that 130 (83.3%) surgical departments had systematic reports about resistance data.

Hospital pharmacists inside the multidisciplinary team should negotiate with hospital administration to obtain adequate and necessary infrastructure to measure antimicrobial use. Regular feedback about antimicrobial consumption can be an important determinant for change for healthcare professionals and policy makers to expedite progress towards prudent use of antimicrobials. The survey showed that 129 (81.6%) surgical departments had an antimicrobial monitoring system.

Interestingly, 6 (6/41, 14.6%) surgical departments implementing a formulary restriction do not perform any monitoring system of used antimicrobials, and 4 (4/41, 9.8%) do not carry out any systematic reports about resistance data. Furthermore, 6 (7/70, 10.0%) surgical departments using a compulsory order form do not perform any monitoring system of used antimicrobials, and 11 (11/70, 15.7%) do not carry out any systematic reports about resistance data. In institutions that use restrictive interventions, monitoring overall trends in antimicrobial use and systematic reports about resistance data should be necessary to assess and respond to such shifts in use.

The ultimate goal of any stewardship program should be to stimulate a behavioral change in prescribing practices. In this context, education of prescribers is crucial to convince clinicians to use antibiotics judiciously. However, without concurrent interventions education alone is of little value. In this regard, various stewardship interventions have been implemented with the aim of improving adherence to guidelines. Where these interventions have been clinician focused, accumulating evidence suggests that educational interventions are mostly ineffective and result in insignificant changes to overall compliance [17]. It is possible that this might relate to cognitive dissonance, a process in which clinician-focused education fails to engage prescribers effectively, allowing them to ignore the evidence and to continue with their regular habits and practices. Alternative strategies of improving antibiotic management of surgical patients are needed and these may include guidance of clinicians in the institutional process of improvement, which has not as yet been addressed in guidelines [17]. The answer may lie within the principles and imperatives contained with the change of processes in hospitals.

It is highly important that faculty in academic medical centers and teaching hospitals focus on fundamental antibiotic stewardship principles in their preclinical and clinical curricula [18].

The survey found that dissemination of educational materials and educational outreach were developed

respectively in 85 cases (62.5%) and 73 (53.7%) surgical departments.

This study has several limitations: with a response rate of just 19.4% we have to consider a response bias, and it is possible that non-participating physicians may have been less interested in ASPs than the participants and therefore it is possible that results are biased towards a better picture than it actually is. Furthermore, the study was conducted in a sample of physicians who participated in the AGORA project, and selecting international experts in the field again potentially resulting in an overrepresentation of hospitals with a considerably active ASP. No stratification or sampling according to medical specialty were pre-planned to ensure that all stakeholders were adequately represented, and finally our questionnaire was self-reported, has not been externally validated, and was evaluated in a single institution. The major strength of the study is its multinational (global) and multidisciplinary approach, to our best knowledge the first in this setting. Thus, our survey provides a benchmark to all interested stakeholders; it can be repeated over time to explore if better uniformity on a global platform of healthcare environments would develop in the future, and may be used to build consensus around the best practices in the field of prevention of surgical infections and rational use of antibiotics in a future project.

Conclusions

The results of the survey showed a heterogeneous organization of ASPs worldwide and demonstrated the need for a cohesive approach in order limit the emergence of antimicrobial resistance in surgical infections. Successful ASPs should focus on collaboration between all healthcare professionals in order to gain the wider-possible acceptance, share knowledge and spread best clinical practices. The main bias of the survey is the low response rate.

Additional file

Additional file 1: The international cross-sectional survey. (DOC 56 kb)

Abbreviation

ASP: Antimicrobial stewardship program

Acknowledgements

Not applicable.

Funding

None.

Availability of data and materials

Not applicable.

Authors' contributions

MS wrote the first draft of the manuscript. All the authors reviewed the manuscript and approved the final draft.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Author details

¹Department of Surgery, Macerata Hospital, Macerata, Italy. ²Department of Biomedical Sciences and Public Health, Unit of Hygiene, Preventive Medicine and Public Health, Università Politecnica delle Marche, Ancona, Italy.

³Infectious Diseases Unit, Bolzano Central Hospital, Bolzano, Italy. ⁴General Surgery Department, Papa Giovanni XXIII Hospital, Bergamo, Italy.

⁵Department of Clinical microbiology, Ampath National Laboratory Services, Milpark Hospital, Johannesburg, South Africa. ⁶Division of Infectious Diseases and HIV Medicine, Department of Medicine, University of Cape Town, Cape town, South Africa. ⁷World Alliance against Antibiotics Resistance, Rome, Italy.

⁸Center for Critical Care, Anaesthesiology Institute and Department of Outcomes Research, Cleveland Clinic, Cleveland, OH, USA. ⁹Department of Surgery and Obstetrics/Gynaecology, Regional Hospital, Limbe, Cameroon.

¹⁰Department of Surgery, Infermi Hospital, Rimini, Italy. ¹¹Department of Surgery, Maggiore Hospital, Bologna, Italy. ¹²Department of Surgery, Vanderbilt University Medical Center, Nashville, Tennessee, USA. ¹³Infectious Diseases Unit, Department of Medical and Surgical Sciences, Sant'Orsola Hospital, University of Bologna, Bologna, Italy. ¹⁴Division of Infectious Diseases, Cleveland Clinic Akron General, Akron, OH, USA. ¹⁵Department of Medicine, Northeast Ohio Medical University, Rootstown, OH, USA. ¹⁶Clinical Epidemiology Unit, IRCCS Policlinico San Matteo Foundation, Pavia, Italy.

¹⁷Division of Infectious Diseases, Jackson Health System, University of Miami Miller School of Medicine, Miami, FL, USA. ¹⁸Department of Surgery, College of Medicine and Health Sciences, UAE University, Al-Ain, United Arab Emirates. ¹⁹Department of Surgery, College of Health Sciences, Obafemi Awolowo University, Ile-Ife, Nigeria. ²⁰Division of Clinical and Administrative Sciences, College of Pharmacy, Xavier University of Louisiana, New Orleans, LA, USA. ²¹Department of Medicine, Division of Infectious Diseases, University of South Carolina School of Medicine, Columbia, SC, USA. ²²General Surgery Department, Bakirkoy Dr Sadi Konuk Training and Research Hospital, Istanbul, Turkey. ²³Unit of Prevention and Infection Control, Center of Hospital Epidemiology, São João Hospital Centre, Porto, Portugal. ²⁴Infection Control Committee, Prontobaby Hospital da Criança, Rio de Janeiro, Brazil.

²⁵Department of Surgery, University Hospital Center, Zagreb, Croatia.

²⁶Trauma and Acute Care Surgery Unit, Hadassah Hebrew University Medical Center, Jerusalem, Israel. ²⁷Department of Surgery, Weill Cornell Medicine, New York, NY, USA. ²⁸Department of General Surgery, Hospital San Juan de Dios de La Serena, La Serena, Chile. ²⁹Academic Department of Surgery, Queen Elizabeth Hospital, Birmingham, UK. ³⁰Department of Microbiology National Reference Laboratory Cheikh Khalifa Ibn Zaid Hospital, Mohammed 6th University of Health Sciences, Casablanca, Morocco. ³¹Department of Pathology and Laboratory Medicine, VA Boston HealthCare System, Boston, MA, USA. ³²Department of Pathology and Laboratory Medicine, Boston University School of Medicine, Boston, MA, USA. ³³Department of Surgery, Hospital Clínico Universitario, Santiago de Compostela, Spain. ³⁴Hospital Epidemiology and Infectious Diseases, Hospital Universitario Dr Jose Eleuterio Gonzalez, Monterrey, Mexico. ³⁵Department of Emergency, Umberto I Hospital, Rome, Italy. ³⁶Department of Pharmacology, Pushpagiri Institute of Medical Sciences and Research Centre, Thiruvalla, Kerala, India. ³⁷Department of General Surgery, Kuala Krai Hospital, Kuala Krai, Kelantan, Malaysia.

³⁸Division of Acute Care Surgery, Department of Surgery, University of Michigan, Ann Arbor, MI, USA. ³⁹Niguarda Hospital, Milano, Italy.

⁴⁰Department of General Surgery, Health Sciences University, Samsun Training and Research Hospital, Samsun, Turkey. ⁴¹Department of Internal Medicine and Infectious Diseases, University of Cologne, Cologne, Germany.

⁴²Department of Surgery, Tianjin Nankai Hospital, Nankai Clinical School of Medicine, Tianjin Medical University, Tianjin, China. ⁴³Department General

Surgery, Kipshidze Central University Hospital, Tbilisi, Georgia. ⁴⁴Department of Digestive Surgery, Cannes Hospital, Cannes, France. ⁴⁵Department of Critical Care Medicine, Ghent University Hospital, Ghent, Belgium. ⁴⁶School of Pharmacy, Faculty of Medical Sciences, The University of the West Indies, St. Augustine, Trinidad and Tobago. ⁴⁷Eric Williams Medical Sciences Complex, Uriah Butler Highway, Champ Fleurs, Trinidad and Tobago. ⁴⁸Department of Surgery, Versilia Hospita, Lido di Camaiore, Italy. ⁴⁹Department of Surgery, University Hospital of Trauma, Tirana, Albania. ⁵⁰School of Pharmacy and Biomedicine, Mongolian National University of Medical Sciences, Ulaanbaatar, Mongolia. ⁵¹Department of Microbiology, Bicêtre Hospital, Paris-Sud University, La Kremlin-Bicêtre, France. ⁵²Department of Surgery, John Peter Smith Health Network, Fort Worth, Texas, USA. ⁵³Sudan National Public Health Laboratory, Federal Ministry of Health, Khartoum, Sudan.

⁵⁴Department of Medicine, Infectious Disease Division, King Fahad Medical City, Riyadh, Saudi Arabia. ⁵⁵Department of Surgery, Virginia Commonwealth University, Richmond, VA, USA. ⁵⁶Department of Surgery, Clinica Foianini, Santa Cruz, Bolivia. ⁵⁷Department of Abdominal Surgery, Vladimir City Clinical Hospital of Emergency Medicine, Vladimir, Russia. ⁵⁸Department of Surgery, Bharati Vidyapeeth Deemed University Medical College and Hospital, Sangli, Maharashtra, India. ⁵⁹Department of General Surgery, Mansoura Faculty of Medicine, Mansoura University, Mansoura, Egypt. ⁶⁰Sixth Department of Internal Medicine, Hygeia General Hospital, Athens, Greece. ⁶¹Second Department of Surgery, Aretaieion University Hospital, National and Kapodistrian University of Athens, Athens, Greece. ⁶²Center for Global Health, Mito Kyodo General Hospital, University of Tsukuba, Mito, Ibaraki, Japan.

⁶³University Department for Tumours, Sestre Milosrdnice UHC, Zagreb, Croatia. ⁶⁴General and Upper GI Surgery, Queen Elizabeth Hospital, Birmingham, UK. ⁶⁵Peruvian Navy Medical Center, Lima, Peru. ⁶⁶Department of Gastrointestinal Surgery, Santa Casa Hospital, Campo Grande, Brazil.

⁶⁷Trauma and Trauma ICU, Inkosi Albert Luthuli Central Hospital and Department of Surgery, University of KwaZulu-Natal, Durban, South Africa.

⁶⁸Department of General and Thoracic Surgery, University Hospital Giessen, Giessen, Germany. ⁶⁹Department of Surgery, Faculty of Medicine, University of Parakou, BP 123 Parakou, Benin. ⁷⁰Fourth Surgical Department, General Hospital G. Papanikolaou, Medical School, Aristotle University of Thessaloniki, Thessaloniki, Greece. ⁷¹Department of General Surgery, Erzincan University, Faculty of Medicine, Erzincan, Turkey. ⁷²Department of Pharmacy, Lebanese, International University, Beirut, Lebanon. ⁷³Drug Applied Research Center, Tabriz University of Medical Sciences, Tabriz, Iran. ⁷⁴Division of Infectious Diseases, American University of Beirut, Beirut, Lebanon. ⁷⁵Department of Surgery Philadelphia VA Medical Center, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, USA. ⁷⁶Department of Microbiology, Gandhi Medical College, Bhopal, India. ⁷⁷Clinic for Emergency Surgery, Medical Faculty University of Belgrade, Belgrade, Serbia. ⁷⁸Third Department of General Surgery, Jagiellonian University Medical College, Krakow, Poland. ⁷⁹Department of Abdominal Surgery, Regional Hospital of Tienen, Tienen, Belgium. ⁸⁰Department of Internal Medicine, Royal Hospital, Muscat, Oman. ⁸¹Department of Emergency Surgery, City Hospital, Mozyr, Belarus. ⁸²Department of Pharmacology and Therapeutics, College of Health Sciences, Makerere University, Kampala, Uganda. ⁸³Department of Internal Medicine, Seoul National University Bundang Hospital, Seongnam, Republic of Korea. ⁸⁴Department of Internal Medicine, National Cheng Kung University Hospital, Tainan, Taiwan. ⁸⁵Department of Primary Care and Emergency Medicine, Kyoto University Graduate School of Medicine, Kyoto, Japan.

⁸⁶Department of Surgery n. 2, Higher educational institutions of Ukraine Bukovina State Medical University, Chernivci City, Ukraine. ⁸⁷Section of Critical Care Medicine and Section of Infectious Diseases, Department of Medicine, Medical Microbiology and Pharmacology/Therapeutics, University of Manitoba, Winnipeg, MB, Canada. ⁸⁸Hospital Central Dr Ignacio Morones Prieto, San Luis Potosi, Mexico. ⁸⁹Department of Surgery, Division of Trauma, University of Arizona, Tucson, AZ, USA. ⁹⁰Department of Surgery, Yonsei University College of Medicine, Seoul, South Korea. ⁹¹Texas Tech University, Health Sciences Center School of Pharmacy, Abilene, TX, USA. ⁹²Abdominal Center, University Hospital Meilahti, Helsinki, Finland. ⁹³Department of Surgery, Inling Hospital, Nanjing University School of Medicine, Nanjing, China. ⁹⁴Division of Infectious Diseases, Division of Emergency Medicine, Washington University School of Medicine, St. Louis, MO, USA. ⁹⁵Clinical Microbiology and Infectious Diseases, School of Pathology, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa.

⁹⁶Department of Surgery, Universidad Nacional de Asuncion, Asuncion, Paraguay. ⁹⁷Department for Traumatology and Orthopedic Surgery, Cologne

Merheim Medical Center (CMMC), University of Witten/Herdecke (UW/H), Cologne, Germany. ⁹⁸Second Department of General Surgery, Jagiellonian University Medical College, Krakow, Poland. ⁹⁹Health Research Program, Institute of Economic and Social Research, University of Zambia, Lusaka, Zambia. ¹⁰⁰Clinical Research Center, Fundacion Valle del Lili, Cali, Colombia. ¹⁰¹First Department of Surgery, Tzaneion General Hospital, Piraeus, Greece. ¹⁰²Service of General Surgery, Hospital Complex of Jaén, Jaén, Spain. ¹⁰³Department of Surgery, Post-Graduate Institute of Medical Sciences, Rohtak, India. ¹⁰⁴Servicio de Anestesia y Reanimación, Hospital Universitario La Paz Madrid, Madrid, Spain. ¹⁰⁵Department of Surgery, Radiology, University Hospital of the West Indies, Kingston, Jamaica. ¹⁰⁶Infectious Diseases Division, Department of Medicine, Prince Mohamed Bin Abdulaziz Hospital, Ministry of Health, Riyadh, Saudi Arabia. ¹⁰⁷Departments of Medicine, Clinical Epidemiology and Biostatistics, and Pathology and Molecular Medicine, McMaster University, Hamilton, ON, Canada. ¹⁰⁸Second Surgical Clinic, Emergency Hospital of Craiova, Craiova, Romania. ¹⁰⁹Department of Microbiology, Tribhuvan University Teaching Hospital, Institute of Medicine, Kathmandu, Nepal. ¹¹⁰Department of Surgery, University of Colorado, Denver Health Medical Center, Denver, CO, USA. ¹¹¹Department of Surgery, Onandjokwe Hospital, Ondangwa, Namibia. ¹¹²Infectious Diseases Division, Warren Alpert Medical School of Brown University, Rhode Island Hospital, Providence, RI, USA. ¹¹³Department of Surgery, University of Michigan, Ann Arbor, MI, USA. ¹¹⁴Department of Surgery, Emergency Hospital of Bucharest, Bucharest, Romania. ¹¹⁵Clinic for General Surgery, Clinical Centre, NIS, Serbia. ¹¹⁶Center of Anti-Infective Research and Development, Hartford, CT, USA. ¹¹⁷Department of Surgery, King Abdullah University Hospital, Irbid, Jordan. ¹¹⁸Department of Surgery and Critical Care, Universidad del Valle, Fundación Valle del Lili, Cali, Colombia. ¹¹⁹Intensive Care Medicine Department, Centro Hospitalar São João, University of Porto, Porto, Portugal. ¹²⁰Department of Microbiology, Grande International Hospital, Dhapasi, Kathmandu, Nepal. ¹²¹Department of Surgery, Santa Casa de Sao Paulo School of Medical Sciences, São Paulo, Brazil. ¹²²Department of General and Emergency Surgery, University Hospital Kraków, Kraków, Poland. ¹²³Department of Surgery, University of Campinas, Campinas, Brazil. ¹²⁴Laboratory of Clinical Microbiology, Department of Infectious Diseases, Instituto Nacional de Ciencias Médicas y Nutrición Salvador Zubirán, Mexico City, Mexico. ¹²⁵Fourth Department of Internal Medicine and Infectious Diseases Unit, National and Kapodistrian University-Medical School, Attikon University General Hospital, Athens, Greece. ¹²⁶John Farman Intensive Care Unit, University Hospitals, NHS Foundation Trust, Cambridge, UK. ¹²⁷Infectious and Tropical Diseases Department, University Hospital of Nancy, and EA 4360 APEMAC, Lorraine University, Nancy, France. ¹²⁸Department of General and Emergency Surgery, Riga East University Hospital 'Gailezers', Riga, Latvia. ¹²⁹Department of Trauma, Hospital Santo Tomas, Panama, Panama. ¹³⁰National Institute for Health Research, Health Protection Research Unit in Healthcare Associated Infections and Antimicrobial Resistance, Imperial College London, Hammersmith Campus, London, UK. ¹³¹Emergency Post-operative Department, Otavio de Freitas Hospital and Hosvaldo Cruz Hospital, Recife, Brazil. ¹³²Department of General Surgery, Jesenice General Hospital, Jesenice, Slovenia. ¹³³Trauma and Acute Care Service, St Michael's Hospital, University of Toronto, Toronto, Canada. ¹³⁴Burns, Trauma and Critical Care Research Centre, The University of Queensland, Brisbane, Queensland, Australia. ¹³⁵Unidad Clínica Intercentros de Enfermedades Infecciosas, Microbiología y Medicina Preventiva, Hospitales Universitarios Virgen Macarena y Virgen del Rocío-IBIS and Departamento de Medicina, Universidad de Sevilla, Seville, Spain. ¹³⁶General Surgery Department, Medical University, University Hospital St George, Plovdiv, Bulgaria. ¹³⁷JPS Health Network, Texas, TX, USA. ¹³⁸Hospital Center Tondela Viseu, Tondela, Portugal. ¹³⁹Department of Aeromedical Services for Emergency and Trauma Care, Ehime University Graduate School of Medicine, Ehime, Japan. ¹⁴⁰Department of Surgery, University of Virginia Health System, Charlottesville, VA, USA. ¹⁴¹Department of Surgery, University of Sao Paulo, Ribeirao Preto, Brazil. ¹⁴²Unit of Hospital Pharmacy, Macerata Hospital, Macerata, Italy. ¹⁴³Department of Pharmacology, Postgraduate Institute of Medical Education and Research, Chandigarh, India. ¹⁴⁴Department of General Surgery, Tan Tock Seng Hospital, Tan Tock Seng, Singapore. ¹⁴⁵Office of Hospital Epidemiology/ Infection Prevention and Control, University of Virginia Health System, Charlottesville, VA, USA. ¹⁴⁶Department of Surgery, Faculty of Medicine, Thammasat University Hospital, Thammasat University, Pathum Thani, Thailand. ¹⁴⁷Department of Gastrointestinal Surgery, Stavanger University Hospital, Stavanger, Norway. ¹⁴⁸Department of Clinical Medicine, University

of Bergen, Bergen, Norway. ¹⁴⁹Department of Emergency Surgery and Critical Care, Centro Medico Imbanaco, Cali, Colombia. ¹⁵⁰Department of Surgery, School of Medicine, Pontificia Universidade Católica do Rio Grande do Sul (PUCRS), Porto Alegre, Brazil. ¹⁵¹Department of Surgery, North Estonia Medical Center, Tallinn, Estonia. ¹⁵²Department of Molecular Biology, Tran Hung Dao Hospital, No 1, Tran Hung Dao Street, Hai Ba Trung Dist, Hanoi, Vietnam. ¹⁵³Department of Infectious Diseases, John Peter Smith Health Network, Fort Worth, Texas, USA. ¹⁵⁴Institute of Infectious Diseases, Catholic University, Rome, Italy. ¹⁵⁵First Department of Surgery—Department of Abdominal, Thoracic Surgery and Traumatology, General University Hospital, Prague, Czech Republic. ¹⁵⁶Department of Surgery, Medical University of Graz, Graz, Austria. ¹⁵⁷Department of Surgery, Radboud University Nijmegen Medical Center, Nijmegen, The Netherlands. ¹⁵⁸Department of Surgery, Medical School University of Pécs, Pécs, Hungary. ¹⁵⁹Department of Urology, Pediatric Urology and Andrology, Medical Faculty of the Justus Liebig University Giessen, Giessen, Germany. ¹⁶⁰State Key Laboratory for Diagnosis and Treatment of Infectious Diseases, The First Affiliated Hospital, Zhejiang University, Zhejiang, China. ¹⁶¹Trauma and Emergency Surgery Department, Chang Gung Memorial Hospital, Taoyuan City, Taiwan. ¹⁶²Department of Antibiotics and Infection Control, Rudolfstiftung Hospital, Vienna, Austria. ¹⁶³Infection Control Unit, Angers University, CHU d'Angers, Angers, France. ¹⁶⁴Division of Trauma and Surgical Critical Care, DeWitt Daughtry Family Department of Surgery, University of Miami, Miami, FL, USA. ¹⁶⁵Department of Surgery, University of Pittsburgh, Pittsburgh, PA, USA. ¹⁶⁶VU University Medical Center, Amsterdam, The Netherlands. ¹⁶⁷Department of General Surgery, Maggiore Hospital, Parma, Italy.

Received: 19 May 2017 Accepted: 24 July 2017

Published online: 01 August 2017

References

- Sartelli M, Weber DG, Ruppé E, Bassetti M, Wright BJ, Ansaloni L, et al. Antimicrobials: a global alliance for optimizing their rational use in intra-abdominal infections (AGORA). *World J Emerg Surg*. 2016;11:33.
- Davey P, Brown E, Charani E, Fenelon L, Gould IM, Holmes A, et al. Interventions to improve antibiotic prescribing practices for hospital inpatients. *Cochrane Database Syst Rev*. 2013;4:CD003543.
- Howard P, Pulcini C, Levy Hara G, West RM, Gould IM, et al. An international cross-sectional survey of antimicrobial stewardship programmes in hospitals. *J Antimicrob Chemother*. 2015;70:1245–55.
- Pollack LA, Plachouras D, Sinkowitz-Cochran R, Gruhler H, Monnet DL, Weber JT. Transatlantic taskforce on antimicrobial resistance (TATFAR) expert panel on stewardship structure and process indicators. A concise set of structure and process indicators to assess and compare antimicrobial stewardship programs among EU and US hospitals: results from a multinational expert panel. *Infect Control Hosp Epidemiol*. 2016;37:1201–11.
- Sartelli M, Duane TM, Catena F, Tessier JM, Coccolini F, Kao LS, et al. Antimicrobial stewardship: a call to action for surgeons. *Surg Infect*. 2016;17:625–31.
- Dellit TH, Owens RC, McGowan JE Jr, Gerding DN, Weinstein RA, Burke JP, et al. Infectious Diseases Society of America. Society for Healthcare Epidemiology of America Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. *Clin Infect Dis*. 2007;44:159–77.
- Ben-Ishay O, Mitarittono M, Catena F, Sartelli M, Ansaloni L, Kluger Y. Mass casualty incidents - time to engage. *World J Emerg Surg*. 2016;11:8.
- Sartelli M, Catena F, Ansaloni L, Coccolini F, Corbella D, Moore EE, et al. Complicated intra-abdominal infections worldwide: the definitive data of the CIAOW study. *World J Emerg Surg*. 2014;9:37.
- Barlam TF, Cosgrove SE, Abbo LM, MacDougall C, Schuetz AN, Septimus EJ, et al. Implementing an antibiotic stewardship program: guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. *Clin Infect Dis*. 2016;62:e51–77.
- Molloy L, McGrath E, Thomas R, Kaye KS, Rybak MJ. Acceptance of pharmacist-driven antimicrobial stewardship recommendations with differing levels of physician involvement in a Children's hospital. *Clin Pediatr (Phila)*. 2017;56(8):744–51.
- Cakmakci M. Antibiotic stewardship programmes and the surgeon's role. *J Hosp Infect*. 2015;89:264–6.

12. Duane TM, Zuo JX, Wolfe LG, Bearman G, Edmond MB, Lee K, et al. Surgeons do not listen: evaluation of compliance with antimicrobial stewardship program recommendations. *Am Surg.* 2013;79:1269–72.
13. Angus DC, Linde-Zwirble WT, Lidicker J, Clermont G, Carcillo J, Pinsky MR. Epidemiology of severe sepsis in the United States: analysis of incidence, outcome, and associated costs of care. *Crit Care Med.* 2001;29:1303–10.
14. Luyt CE, Bréchet N, Trouillet JL, Chastre J. Antibiotic stewardship in the intensive care unit. *Crit Care.* 2014;18:480.
15. Battle SE, Bookstaver PB, Justo JA, Kohn J, Albrecht H, Al-Hasan MN. Association between inappropriate empirical antimicrobial therapy and hospital length of stay in gram-negative bloodstream infections: stratification by prognosis. *J Antimicrob Chemother.* 2017;72:299–304.
16. Goff DA, Karam GH, Haines ST. Impact of a national antimicrobial stewardship mentoring program: insights and lessons learned. *Am J Health Syst Pharm.* 2017;74:224–31.
17. Brink AJ, Messina AP, Feldman C, Richards GA, van den Bergh D, Netcare. Antimicrobial stewardship study alliance. From guidelines to practice: a pharmacist-driven prospective audit and feedback improvement model for peri-operative antibiotic prophylaxis in 34 south African hospitals. *J Antimicrob Chemother.* 2017;72:1227–34.
18. Pulcini C, Gyssens IC. How to educate prescribers in antimicrobial stewardship practices. *Virulence.* 2013;4:192–202.

Submit your next manuscript to BioMed Central and we will help you at every step:

- We accept pre-submission inquiries
- Our selector tool helps you to find the most relevant journal
- We provide round the clock customer support
- Convenient online submission
- Thorough peer review
- Inclusion in PubMed and all major indexing services
- Maximum visibility for your research

Submit your manuscript at
www.biomedcentral.com/submit

